MIDAS

Materials in Devices as Superconductors

Presentation to the

Spaceflight Experiment Initiatives Review Committee

February 15, 1994

Agenda

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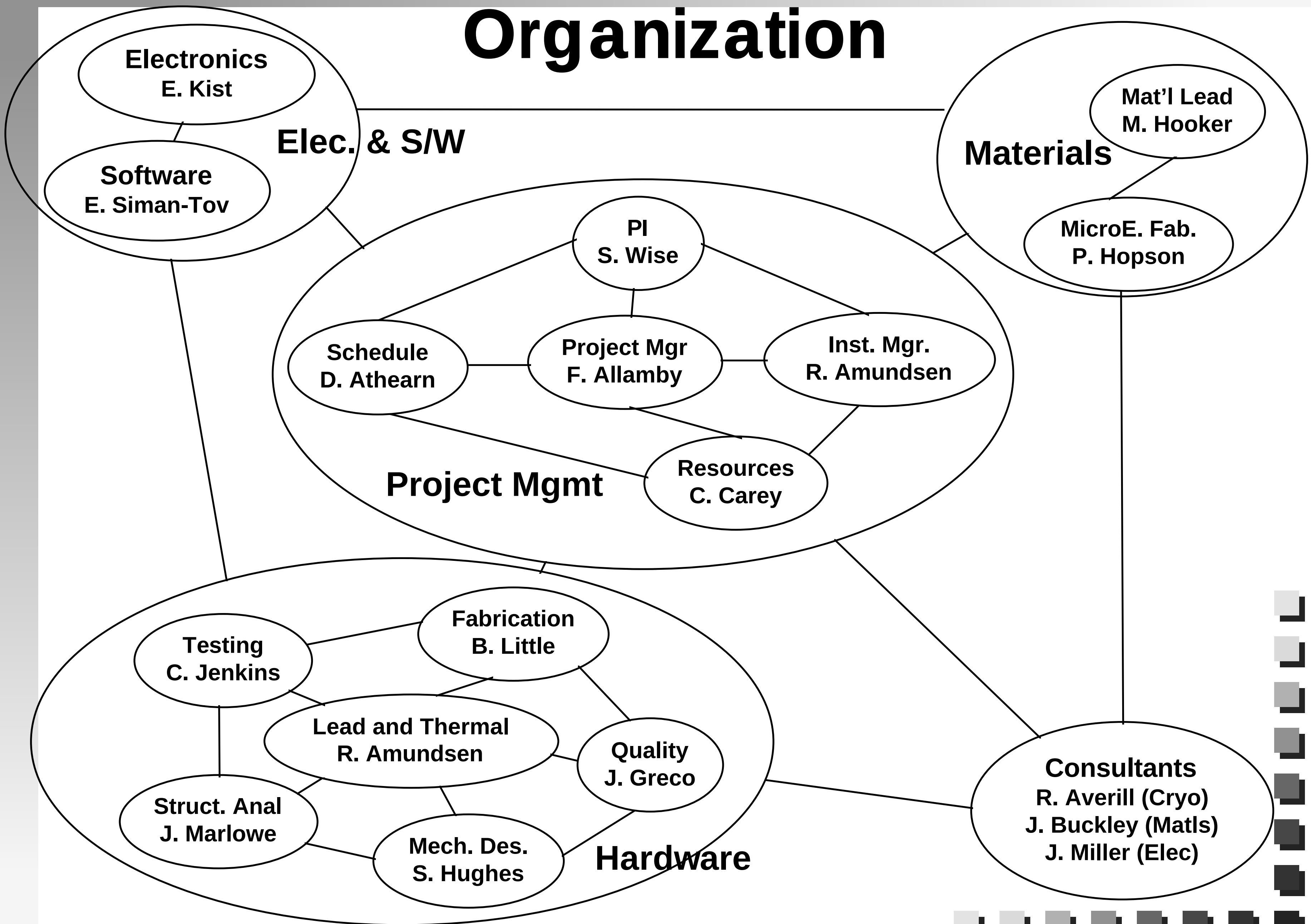
Organization



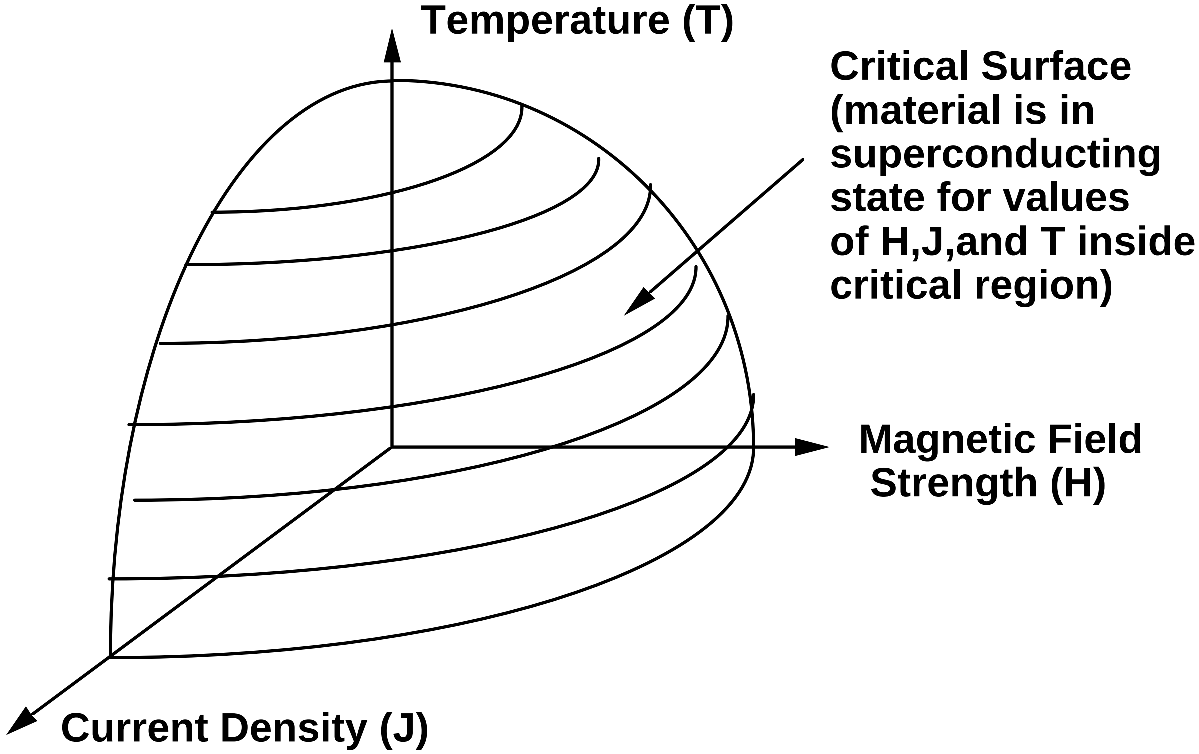
MIDAS Science Objectives and Relevancy to NASA Missions

Dr. Stephanie A. Wise
Flight Electronics Division

High Temperature Superconductivity (HTS)

- Superconductive materials
  - Zero electrical resistance
  - Magnetic levitation
- Measurable properties of superconductors
  - Critical transition temperature, T_c
  - Critical current density, J_c
  - Critical magnetic field, H_c
- High temperature superconductive materials
  - Discovered in 1986
  - Superconduct above 77K
  - Multi-component oxide ceramics

Relationship Between Critical Properties of Superconductors



Relevance to NASA Missions

- Atmospheric remote sensing
  - Thermal isolators for cryogenic detectors
  - Bolometers
  - Cryocooler bearings

- Microwave and millimeter-wave devices
  - Space data processing
  - Communications
  - Navigation/radar/tracking

HTS Thermal Isolators

- **Electrical leads account for Š 20% of the total heat load on stored cryogen (LHe)**
- **Replacement of existing leads with HTS lead assemblies could reduce total heat load by 10-15%**
- **Missions affected include COBE, SAFIRE, AXAF, SIRTF**

Commercialization Potential

- Near-term payoff (3-5 years)
  - Cellular communications
  - Research materials
  - Magnetic Resonance Imaging (MRI)

- Long-term payoff (10+ years)
  - High speed electronics
  - High speed transportation
  - Energy storage

Collaborations

- Industrial Guest Investigators
  - TRW - pulse tube cryocooler
  - AVX, Inc. - thick film electronics, research materials
- University Participation
  - Christopher Newport University - cryogenic testing
  - Clemson University - HTS materials synthesis
  - Virginia Polytechnic Institute - thermal modelling
- Other Gov't Agencies
  - Westinghouse - Savannah River Site - radiation testing

Research Accomplishments To Date

- Synthesized Y-Ba-Cu-O and Bi-Sr-Ca-Cu-O HTS materials
- Evaluated effects of contamination, storage, and thermal cycling on electrical performance
- Demonstrated chemical compatibility and processing of HTS materials on yttria-stabilized zirconia (YSZ) substrates
- Applied thick film processes to the fabrication of HTS circuitry on YSZ

Specimen Design and Fabrication

- Combine HTS thick film processing with conventional electronic thick film circuit to perform T_c and J_c measurements on a 1”x1” YSZ substrate
- Each substrate contains eight HTS elements which are individually characterized throughout the flight
- Temperature is monitored using PRT devices
- Use of multiplexing allows minimization of thermal losses due to electrical wiring

Program Objectives

- Fabricate HTS circuitry for remote sensing and commercial electronic applications

- Evaluate the electrical performance of HTS circuitry during spaceflight

- Validate performance of cryocooler enabling technology in space

Justification for Space Experiment

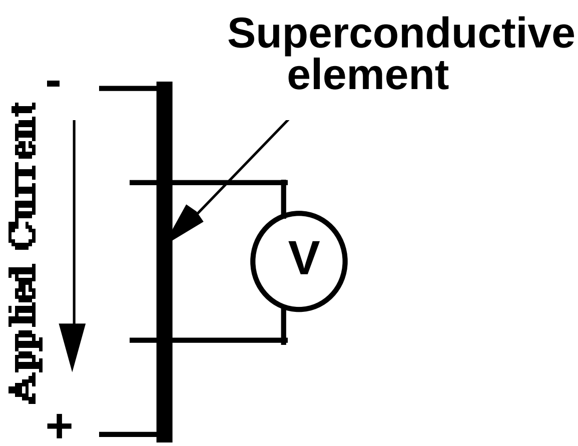
- **No data is available on the performance of HTS materials in the space environment**
- **Electrical performance must be evaluated in the operational environment prior to insertion of HTS devices in space-borne remote sensing instruments and commercial satellite systems**
- **The miniature pulse tube cryocooler provides an enabling technology for remote sensing instruments**

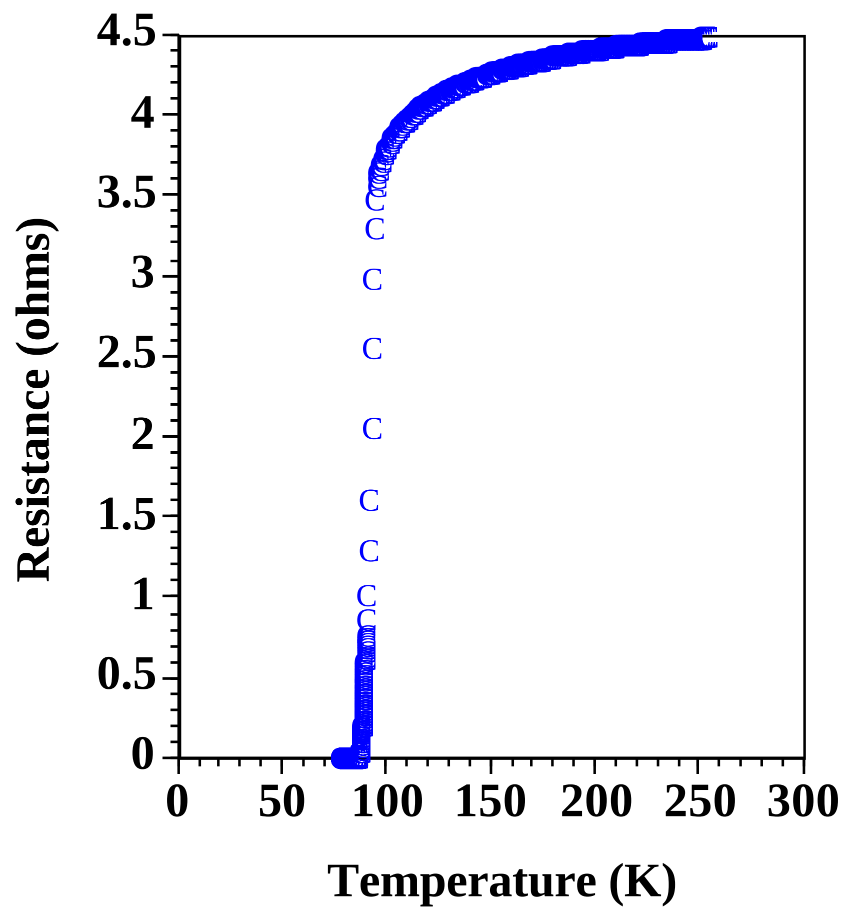
Flight Experiment Approach

- **Evaluate multiple HTS thick film circuits**
- **Monitor T_c during cool-down and warm-up**
- **Monitor J_c periodically during flight**
- **Monitor cryocooler performance**

Superconductive Transition Temperature (T_c)

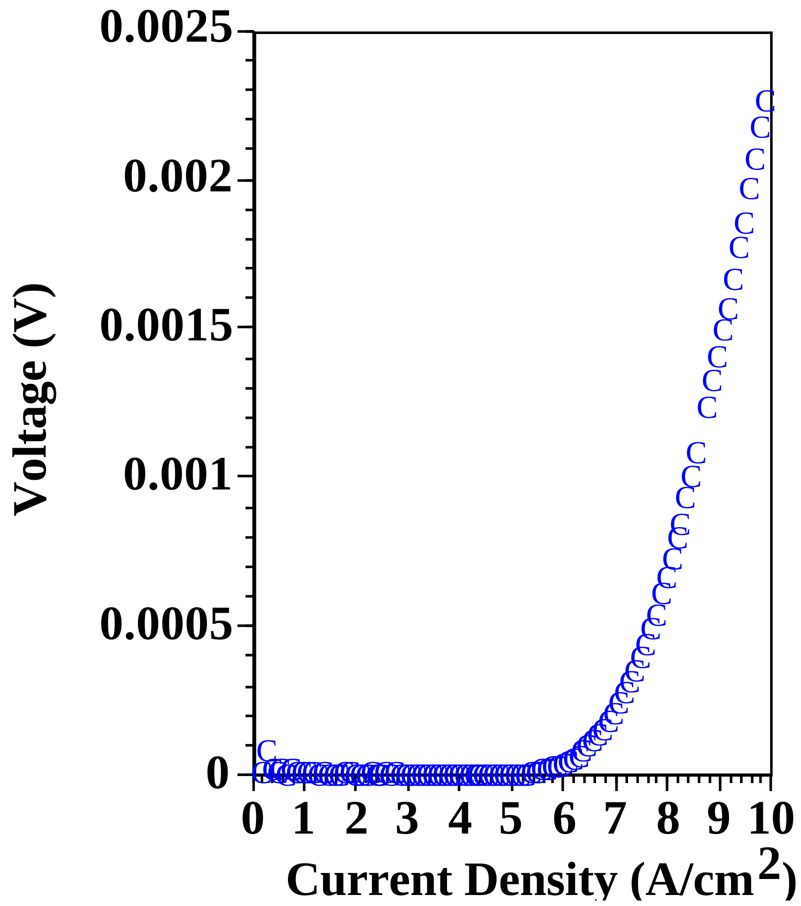
T_c is the temperature below which the material is in a superconductive state. Measured at constant current.





Critical Current Density (J_c)

J_c indicates the maximum current which can be applied to a given specimen without loss of supercon-ductivity. J_c is measured at a constant temperature.



Science Requirements

- Mission Duration
  - 7 days required
  - • 60 days desired
- Number of Test Specimens
  - 4 test circuit boards (HTS/substrate combinations)
  - minimum of 4 HTS elements per board required
  - 8 HTS elements per board desired
- Temperature of Test Specimens
  - 80 K ± 5K required
  - 75 K ± 5K desired
- Temperature Measurement Accuracy
  - ± 0.5 K required
  - ± 0.25 K desired

Science Requirements Cont.

- Thermal Cycling
  - at least 1 cool down cycle
  - at least 1 warm up cycle
- Measurements Performed
  - T_c, J_c
- Measurement Frequency
  - 2 T_c measurements (cool down and warm up)
  - J_c measurement every 30 minutes
- Measurement Accuracy
  - 1μV detection
  - 0-50 A/cm^2 measurement

Science Requirements Cont.

- **Data Returned**
  - **T_c ± 0.5K for each HTS element for each T_c measurement cycle**
  - **“knee” of the curve for each HTS element for each J_c measurement**

MIDAS Systems Development

Ruth Amundsen

<u>Agenda</u>

Derived System Requirements

Instrument Overview

- **Subsystem Descriptions**
- **Weight and Power Estimates**

Programmatics

- **WBS**
- **Schedule**
- **Resources**
- **Cost**

Derived Requirements: Cryocooler

- provide 23.3 W
- ambient temperature 25°C or less
  - minimize electronics box power: <10 W req'd, <5 W goal
- cryocooler regenerator below 35°C
- structural load on cold tip < 0.7 lb
- heat load on cold tip < 400 mW at 75K
  - vacuum level $< 10^{-5}$ torr
  - minimize thermal path of structural support: < 150 mW
  - minimize wires: heat load < 50 mW
  - minimum power components used on boards
  - staggered measurement timing: < 10 mW avg

Derived Requirements: Science

- Electronics and software capability:
  - timing and control for T_c, J_c experiments
  - current source and voltage measurement
  - temperature measurement
  - record temperature and voltage data
- Minimum data rate of 100 KB per day
- Minimum current density for HTS: 1 mA/cm^2

COMET

- Recovery portion in orbit 30 days
- 14.7 psi and 72°F
- Telemetry
- Support Plate: 11” x 32”
- Loads
  - Static - 12 g’s in +X
  - Random - 11.5 Grms (+3 db for test)
- 350 W and 300 lbs among eight experiments
- Delivery 2 months prior to launch
- *NASA HQ recently cautioned us that it is “high risk” to plan for Comet-02*

Derived Requirements: Spacecraft

- **Potential carriers:**
  - Comet-02
  - Eureca
  - Tech Sat
  - Student Explorer
  - Hitchhiker
- **Carrier selection will define:**
  - Launch load and random vibration specs
  - Thermal, pressure, micro-g and radiation environment
  - Telemetry / internal data storage
  - Power, mass, volume and mechanical interface
  - Experiment duration and timing
  - Quality and safety requirements

Potential Flight Carriers

Carrier	Press	Load	Duration	Recov
Comet-02	Y	12 g	30 d	Y
Eureca	N	10 g	6 m	Y
Tech Sat (SSTI)	N	--	3 y	N
Student Expl.	AR	9 g	1 y	N
Hitchhiker	AR	10 g	7 d	Y

Cryocooler Subsystem

- **Includes:**
  - **Cryocooler and control electronics**
  - **Mounting bracket**
  - **Vacuum shroud (carrier dependent)**
- **Completed:**
  - **Design, structural and thermal analysis of subsystem**
  - **Fab of prototype bracket**
  - **Preliminary definition of mechanical and thermal I/F with TRW**

HTS Sample Subsystem

- Includes:
  - HTS hybrid boards
  - Sample mount and thermal block
- Designed and built in-house
- First combination of HTS and conventional electronics on a single board
- Completed:
  - Several prototype boards and ceramic substrates
  - Functional testing of prototypes and design mods
  - Evaluative testing of epoxies for board-to-sink bond
  - Design, analysis and build of prototype sample support

Electronics Subsystem

- Commercial card cage, computer and cards
  - 386, 25MHz microprocessor
  - A/D converter
  - Digital I/O
  - PCMCIA driver and flash memories
  - DC/DC converter
- One board to be designed and built in-house
  - D/A power control for cryocooler and HTS circuit boards
- Completed:
  - Selection and procurement of two development systems
  - Preliminary design of housing and cabling layout
  - Fabrication of housing, prep for vib test of prototype
  - Initial functional test of commercial electronics

Software

- Programming Language -- ADA
  - Extensive re-use of device driver code from LITE
  - Extensive analysis and development tools from SEAL
- Design Methodology
  - Pilot for SEAL S/W Development Guidebook
  - Object-Oriented req's analysis, design and development
  - NDS-2100 documentation
- Completed:
  - Software requirements development based on architectural design
  - COTS software for functional test of card cage and computer system

Weight Estimate

Component	Weight (lbs)
Cryocooler & electronics	9.48
Vacuum shroud & cryocooler support bracket	13.32
HTS samples subsystem	0.20
Electronics box	6.32
Cabling	0.39
Housing and misc. hardware	10.87
Total MIDAS Weight	40.58 lbs

Power Estimate

Component	Power Required (W)
Cryocooler	17
Cryocooler electronics	6
80386 Computer	3
A/D Converter	5
Power conversion @ 75% efficiency	10
Total MIDAS Power	41. W

Resources

CS resources in person-years

Division	FY94	FY95	FY96	Total/div
ACD	0.5	0.5	0.1	1.1
FD	1.0	0.2	0.0	1.2
FED	2.3	0.6	0.2	3.1
PD	1.0	0.7	0.4	2.1
SED	3.9	1.0	0.1	5.0
SSQRD	0.2	0.2	0.1	0.5
Total per FY	8.9	3.2	0.9	13.0

NPS resources

SED/FED	0.5	0.5	0.5	1.5

Cost

150K per year allotted

	FY94	FY95	FY 96
Fab.	62	60	10
Proc.	34	20	
NPS	40	40	40
Cont.	14	30	10
Total	150 K	150 K	60 K